Protecting MV cable insulation from **failure** due to partial discharge

By P Ebersold, Marmon Utility

Why cable designed to be discharge-resistant is the best for ensuring system reliability.

Design engineers must ensure the reliability of solid-dielectric power cable against failures caused by partial discharge (PD), which can be quite a challenging task. Engineers can guard against PD by using two very different methods, designing cable to be either discharge-free or discharge-resistant. *See why designing to the discharge-resistant standard leads to far greater overall system reliability.*

What is PD and why is it harmful to your cable insulation?

PD, or corona, is what electrically ages cable – voids and contaminants are sites where this deterioration begins. PD happens when an electric field inside the void exceeds the breakdown threshold of the gas in the space. The electrical breakdown pulses occurring in microscopic voids and contaminants cause fracturing of the insulation, resulting in points of high stress.

The discharge transfers high energy through ion bombardment onto the surface of the insulation, breaking molecular bonds and degrading the void's internal surfaces by chemical reactions between the polymer and the ionisation by-products. This ionisation process usually occurs over a small portion of the insulation, and the rest continues to work.

PD can also exist in gaps or voids between the insulation and stress-control shields due to improper handling or external damage during installation or operation, as well as in voids and gaps in splices and termination regions due to inferior workmanship and poor fit.

While the existence of PD does not typically cause a catastrophic event like a cable failure immediately, it can harm the cable insulation in the long run, and may lead to premature cable failure.

Two philosophies for dealing with partial discharge

There are two different philosophies for the best way of dealing with PD in power cables.

One approach, used by most major medium voltage cable manufacturers, is to try to eliminate the partial discharge in the manufacturing process, resulting in what is called discharge-free insulation. Because PD occurs in voids, the elimination (discharge-free) approach attempts to ensure that the manufacturing process removes all dischargeable voids. Visual examination with optical microscopy, or, more commonly, factory PD testing, is used to test the cable and label it discharge-free.

However, it is important to understand that the practical limit of current technology means that no cable can be manufactured to be 100% void-free throughout its life. Over time, all cable deteriorates and breaks down. So cable called discharge-free when first manufactured is actually cable with potentially damaging defects, and with less ability to resist the corona effect over time, leading to breakdowns and electrical failure.

The other approach, used by Kerite, is to build partial discharge immunity into the cable insulation by using materials specifically

AEIC – Association of Edison Illuminating Companies
ASTM – American Society for Testing and Materials
EPDM – Ethylene Propylene Diene Monomer
EPM – Ethylene Propylene
EPR – Ethylene Propylene Rubber
ICEA – Insulated Cable Engineers Association
PD – Partial Discharge
PE – Polyethylene
XLPE – Cross-linked Polyethylene

Abbreviations

formulated to resist PD initiated degradation, which results in discharge-resistant cable. Kerite's proprietary ethylene propylene/ethylene propylene diene monomer (EPM/EPDM) - based compounds are formulated, mixed, and extruded in-house with the express goal of resistance to degradation caused by PD.

The discharge-resistant approach recognises that undetectable but dischargeable voids exist in all cable, and that cable reliability depends upon the insulation's ability to operate in the presence of PD. Designs using the discharge resistant approach focus on material development, including the use of tools to enhance the EPR compound ingredients and build in the discharge-resistant characteristics (immunity) that will make the cable insulation extremely long-lasting. PD is intentionally introduced and reactions recorded to evaluate the PD resistance of different materials, since not all materials exhibit the same resistance to partial discharge. *Figure 1* shows the types of materials in the specially formulated compound that build in discharge resistance.

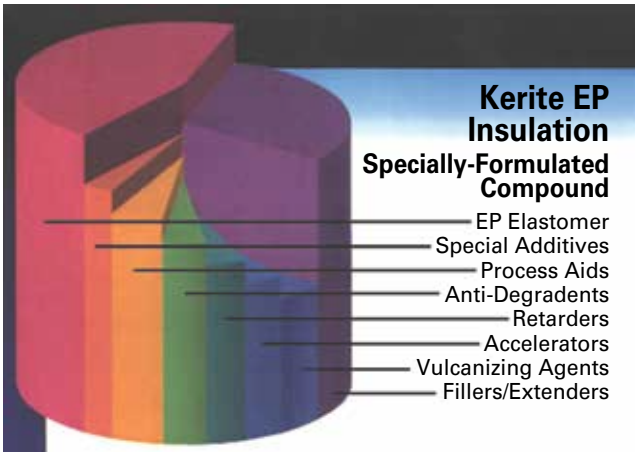

Figure 1: Specially formulated compound resists PD.

Kerite's philosophy is that PD resistance should be a basic requirement for all insulating materials used in power cable. For example, the company uses evaluation methods to introduce discharges on the exterior surface of the insulation and measure how different materials perform. This focus on building PD immunity by making cable that is discharge-resistant is believed to be one of the main contributors for this company's superior field performance, demonstrated by more than a century of empirical evidence and a proven track record. EPR-based cables show no signs of partial discharge over extended periods of time, effectively providing a lifetime guarantee that there will be no electrical failure due to insulation deterioration.

Manufacturing has improved – but no cables are truly discharge-free

Over the past few decades, most cable manufacturers have emphasised the development of new manufacturing technologies designed to reduce voids by making material improvements, including removing contamination in compounds. Together with more stringent factory tests using advanced PD detectors, these new generation cables have come a long way in providing longer life by reducing manufacturing defects that are known to cause PD.

As manufacturing processes have improved, standards for the amount of PD allowed have gone down dramatically, but a certain amount is still allowed – AEIC and ICEA standards currently allow a maximum of 5 Picocoulumbs (pC). The fact of the matter is that no cables are truly discharge-free and current factory partial discharge testing fails to detect potentially damaging defects. These failures cause ageing mechanisms that cannot be eliminated practically. While cable reliability may not be of the same magnitude of concern as 20 years ago, it still matters greatly. Buying premium cable is still critical for ensuring a system's overall reliability.

Testing for partial discharge

Tests for evaluating the effect of PD on cable insulation have been a valuable tool to locate and measure the sites of PD in cable. Typical

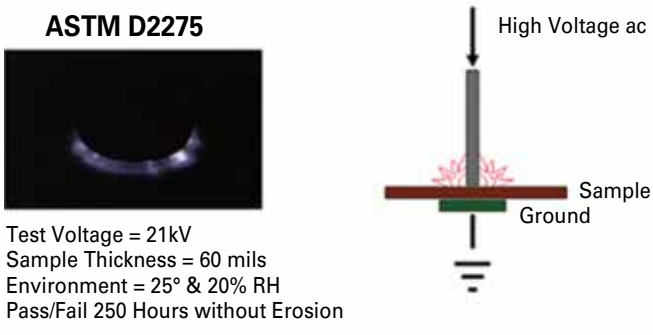

Figure 2: Cylindrical electrode test.

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Peter Ebersold is the director of market and product development for the Kerite and Hendrix brands at Marmon Utility, a Marmon Engineered Wire and Cable/ Berkshire Hathaway Company. Prior to the Marmon Utility, he was a marketing director at Honeywell and a business unit manager at Perkin-Elmer. He started his career as an electrical design engineer. Peter has both Bachelor and Master's degrees in Engineering.

Enquiries: Email powercable@kerite.com Visit www.kerite.com